National Aeronautics and Space Administration

Lunar Architecture - Integrated Analyses and Strategy

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Driven by a Strategy

VSE

ESAS (2005)
Methodical approach to architecture mission mode using relevant FOMS

Global Exploration Strategy (2006)
Lunar Objectives Identified

LAT1 (2006)
Early Outpost at Polar Site

LAT2 (2007)
- *Cargo Lander*
- *Surface Mobility*
- *Cargo Unloading, Transport, Emplacement*

CxAT Lunar (May 2008)
Preparation for the LCCR Transportation System POD

LCCR (June 2008)
Transportation System POD

May 07' The Global Exploration Strategy – The Framework for Coordination

Nov 07' established the International Space Exploration Coordination Group (ISECG)

Jan 08' Start of Chamber of Commerce Interface Standards activity via the SEC

We completed an important milestone

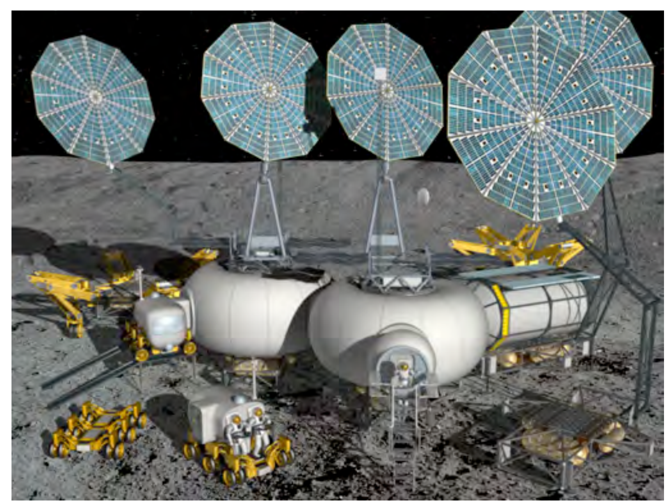
Lunar Capabilities Concept Review

Established Lunar *Transportation* Architecture Point of Departure:

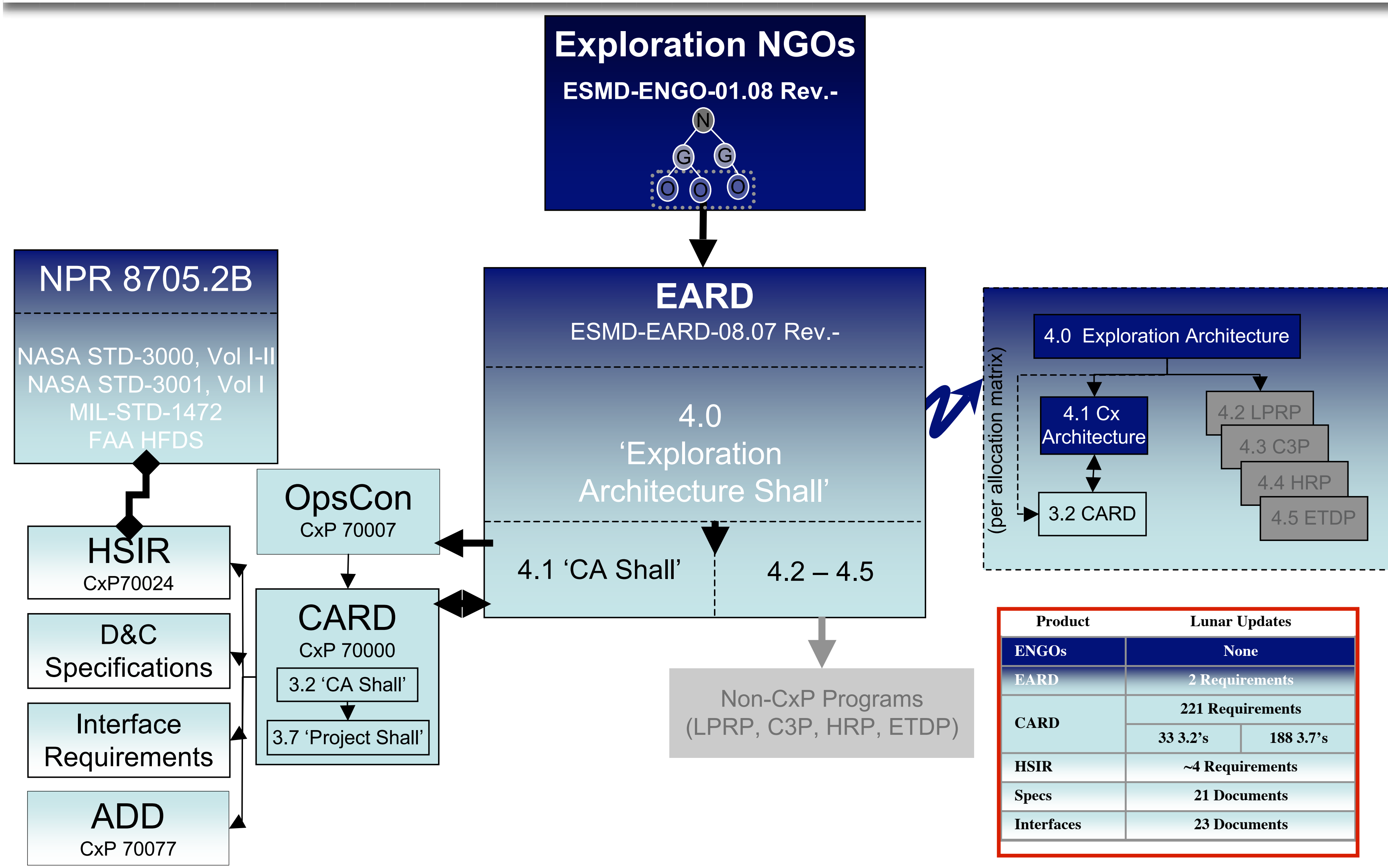
- Provides crew & cargo delivery to & from the moon
- **Provides capacity and capabilities consistent with candidate surface architectures**
- Provides sufficient performance margins
- Remains within programmatic constraints
- Results in acceptable levels of risk

Establish Lunar *Surface* Architectures Strategies which:

- Satisfy NASA NGO's to acceptable degree within acceptable schedule
- **Are consistent with capacity and capabilities of the transportation systems**
- Include set of options for various prioritizations of cost, schedule & risk



Concepts Traced to Needs, Goals and Objectives

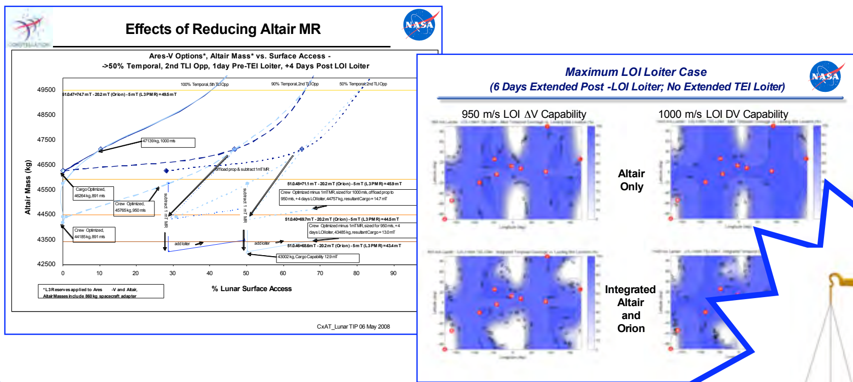


Product	Lunar Updates	
ENGOs	None	
EARD	2 Requirements	
CARD	221 Requirements	
	33 3.2's	188 3.7's
HSIR	~4 Requirements	
Specs	21 Documents	
Interfaces	23 Documents	

Lunar Transportation Figures of Merit - Summary

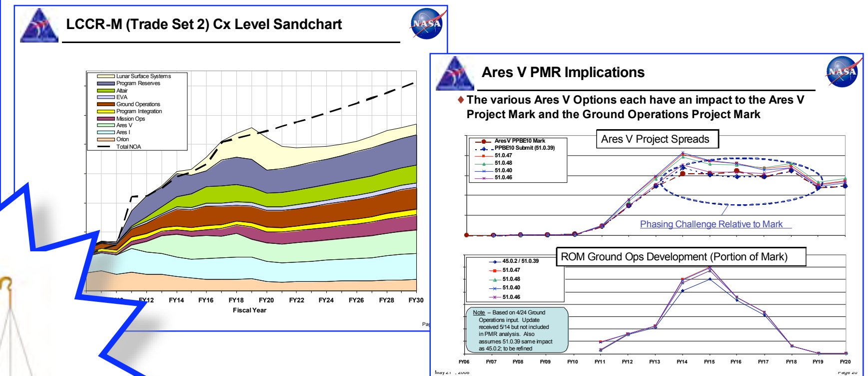
Performance

- Ability to support the lunar outpost
- Mass to surface: crew & cargo
- Robustness of margins by system
- Surface coverage: global access



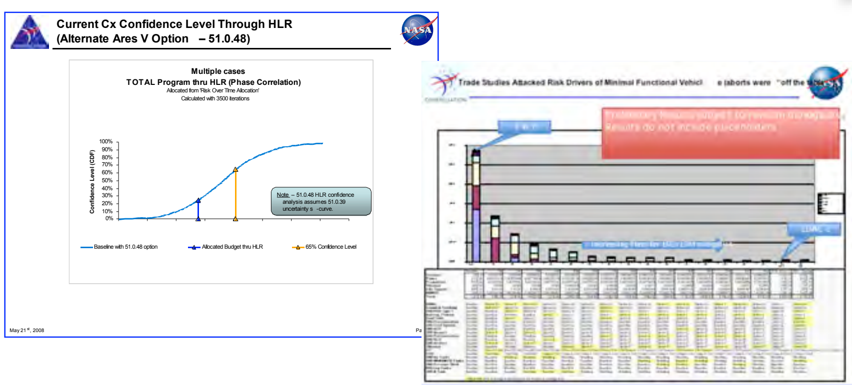
Affordability

- DDT&E
- Recurring
- Budget wedge left for surface systems
- Cost confidence



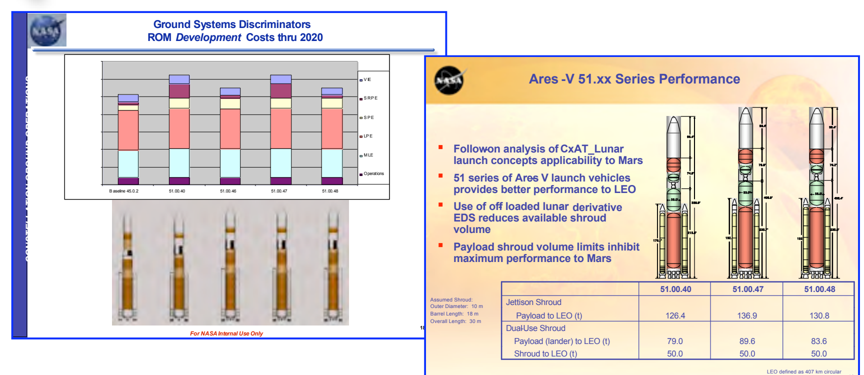
Risk

- LOC / LOM
- Technical performance risk
- Schedule risk
- Commonality



Operations / Extensibility

- Facilities impacts
- Operational flows
- Mars feed-forward



Surface Architecture Characteristics were Examined

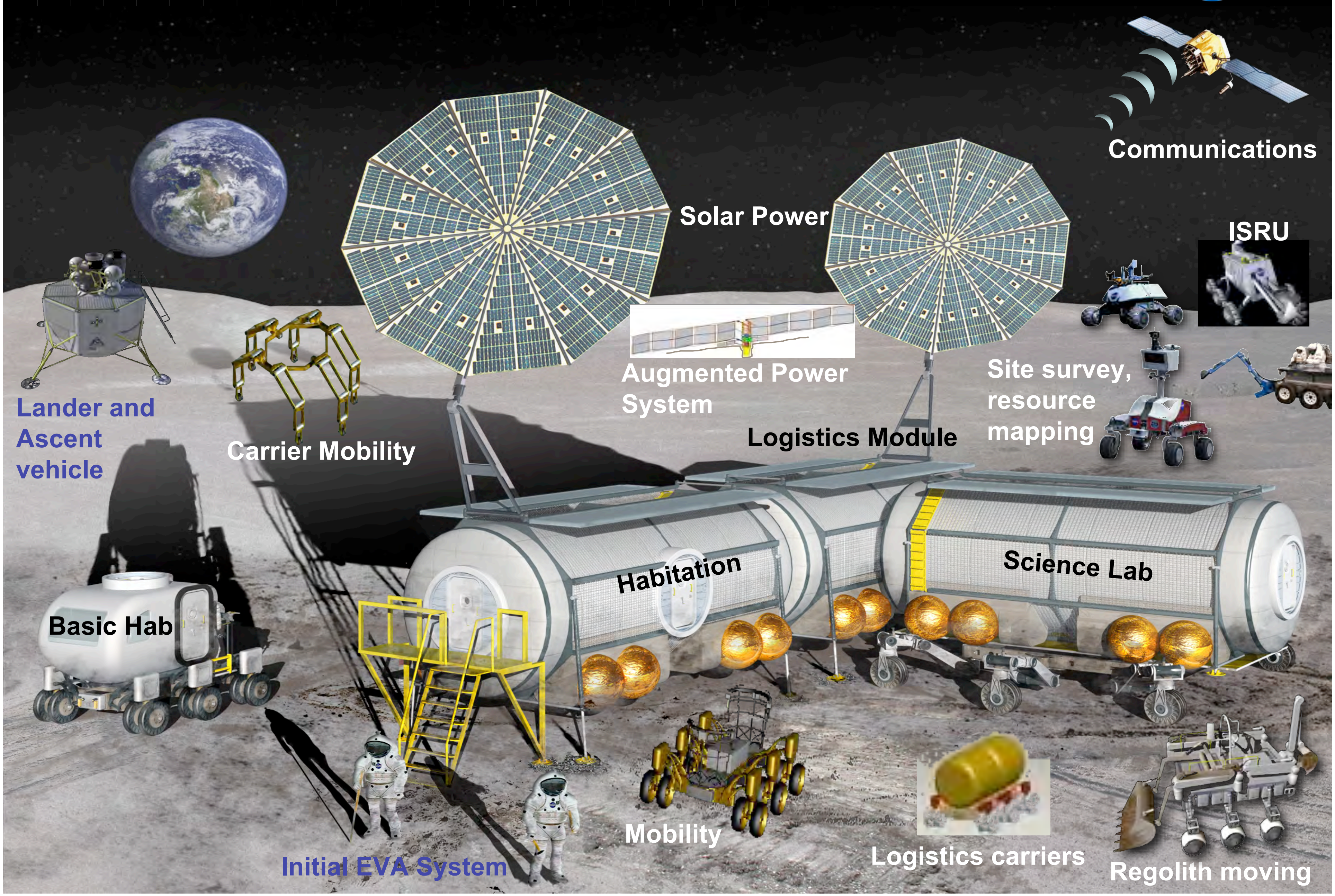
- Pervasive Mobility
  - Science enabler / range extender
  - Ability to adapt outpost elements to more locations on the lunar surface
  - Always something new to explore

- Mission Flexibility
  - Minimally functional outpost capability established as early as possible
  - Outpost can be built at any rate with steadily increasing capabilities: “go as you pay”
  - Outpost can recover rapidly from loss of elements (modular and reconfigurable)
  - Outpost buildup can be adjusted to accommodate changing science & mission priorities

- Global Connectivity
  - The ability to perform global lunar exploration via sorties and long distance roving
  - HD cameras & High bandwidth communications
  - International, commercial & university participation
  - Virtually connecting the above to engage scientists & the general population on both Globes

- Long Duration Missions
  - More time for Science
  - Highly reliable systems
  - Minimize logistics needs
    - In-Situ Resource Utilization, recycling
    - Commonality, repair at board level
  - Outpost can be implemented to emulate Mars surface scenarios
  - Core technologies and operations applicable to Mars exploration

Notional Elements of an Outpost

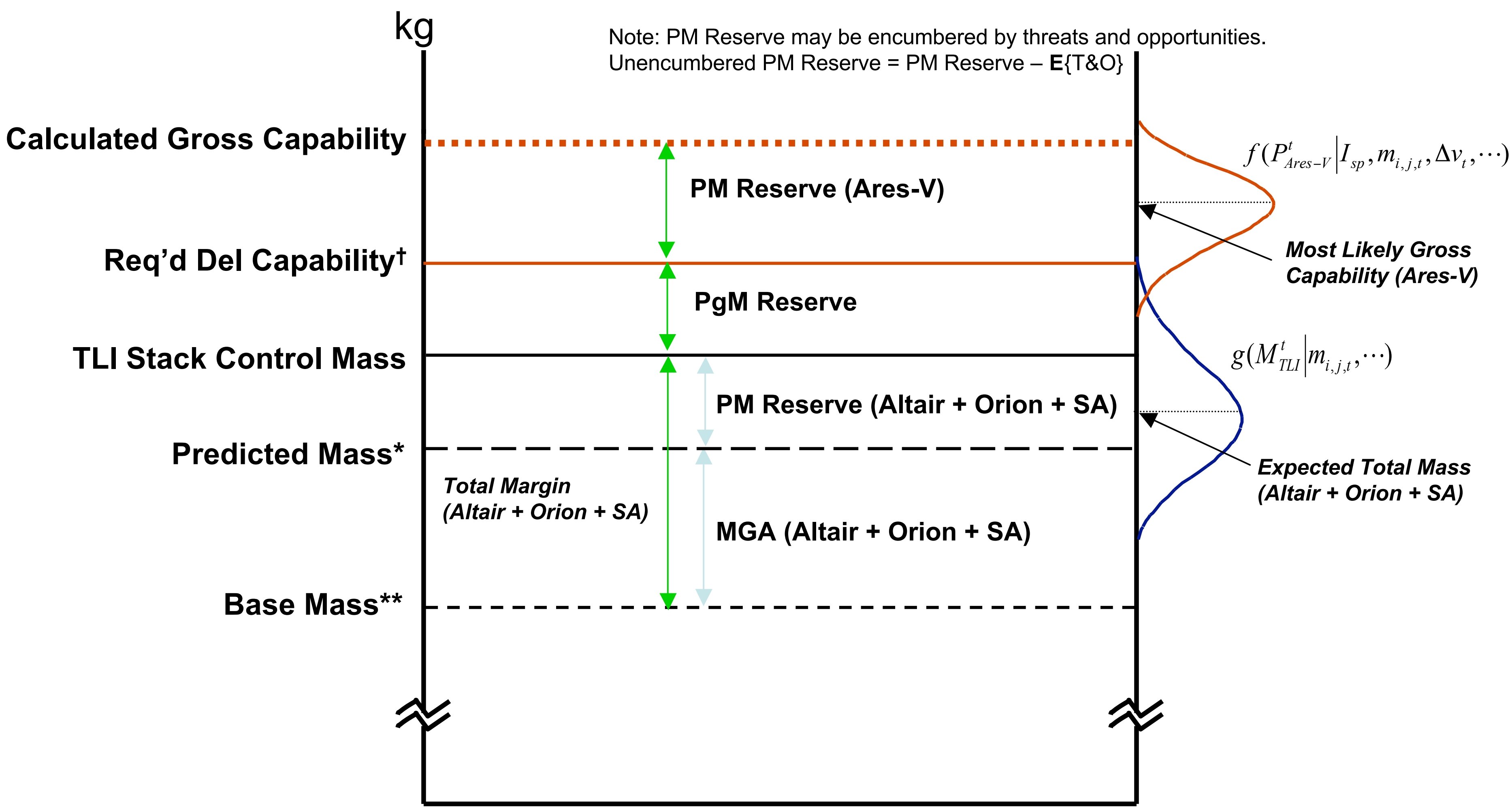


End to End Margin Analysis

Stochastic Margin Analysis Background

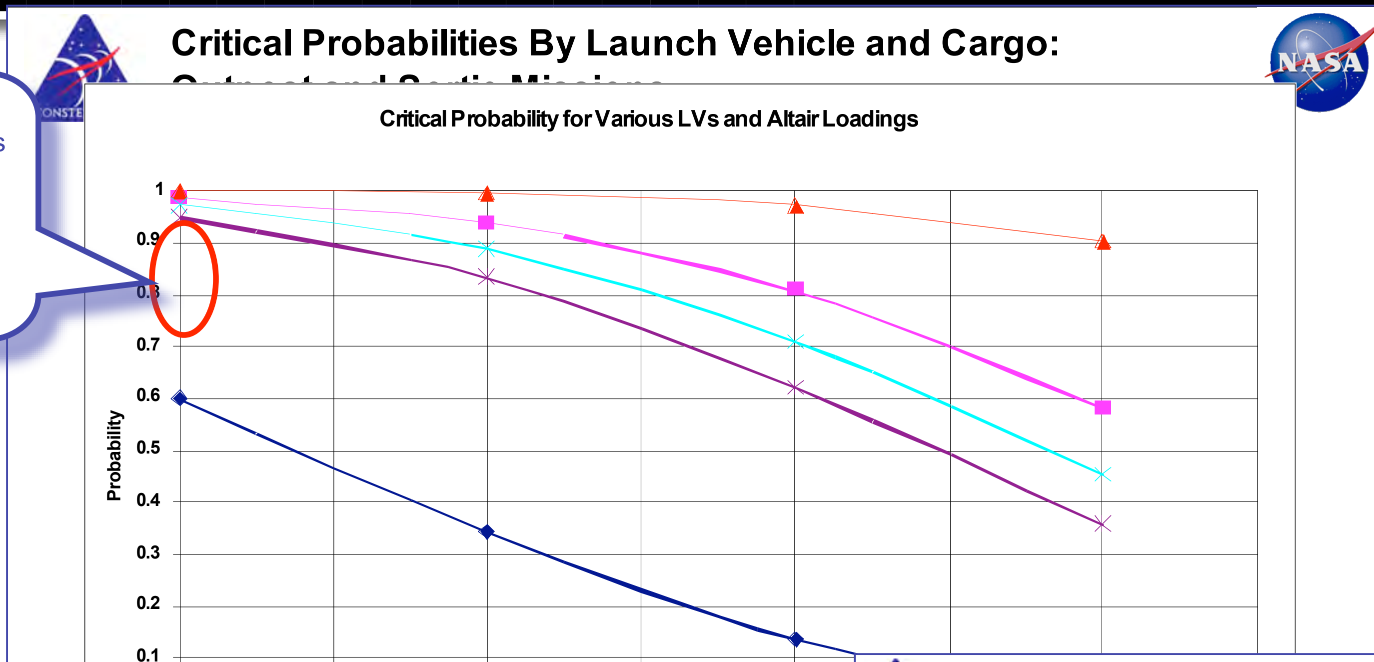
- CxAT-Mass is sponsoring a novel analysis of the margins needed for the lunar transportation phase, including Orion, Altair and Ares V at TLI
- Analysis assesses whether margins are sufficient to ensure success for lunar DRMs with an adequate degree of confidence.
- Analysis is based on Monte Carlo simulation widely used in cost and risk analysis
- The MC simulation models the combined effects of uncertainties in Ares-V/EDS estimated delivery capability and estimated TLI stack mass.
- Completed initial cycles to support CxAT-Lunar architectural decisions at LCCR

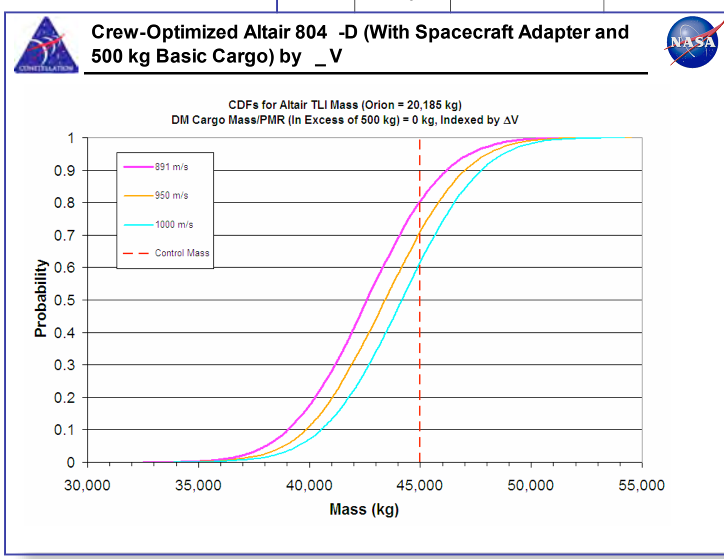
Stochastic Margins Analysis @TLI
(Lunar Outpost Mission)

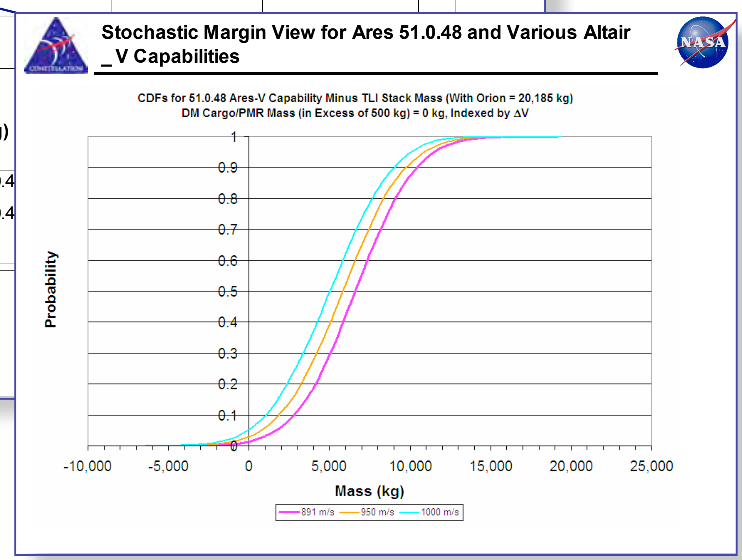


Ares 51.0.48 / Altair Stochastic Margins Assessment

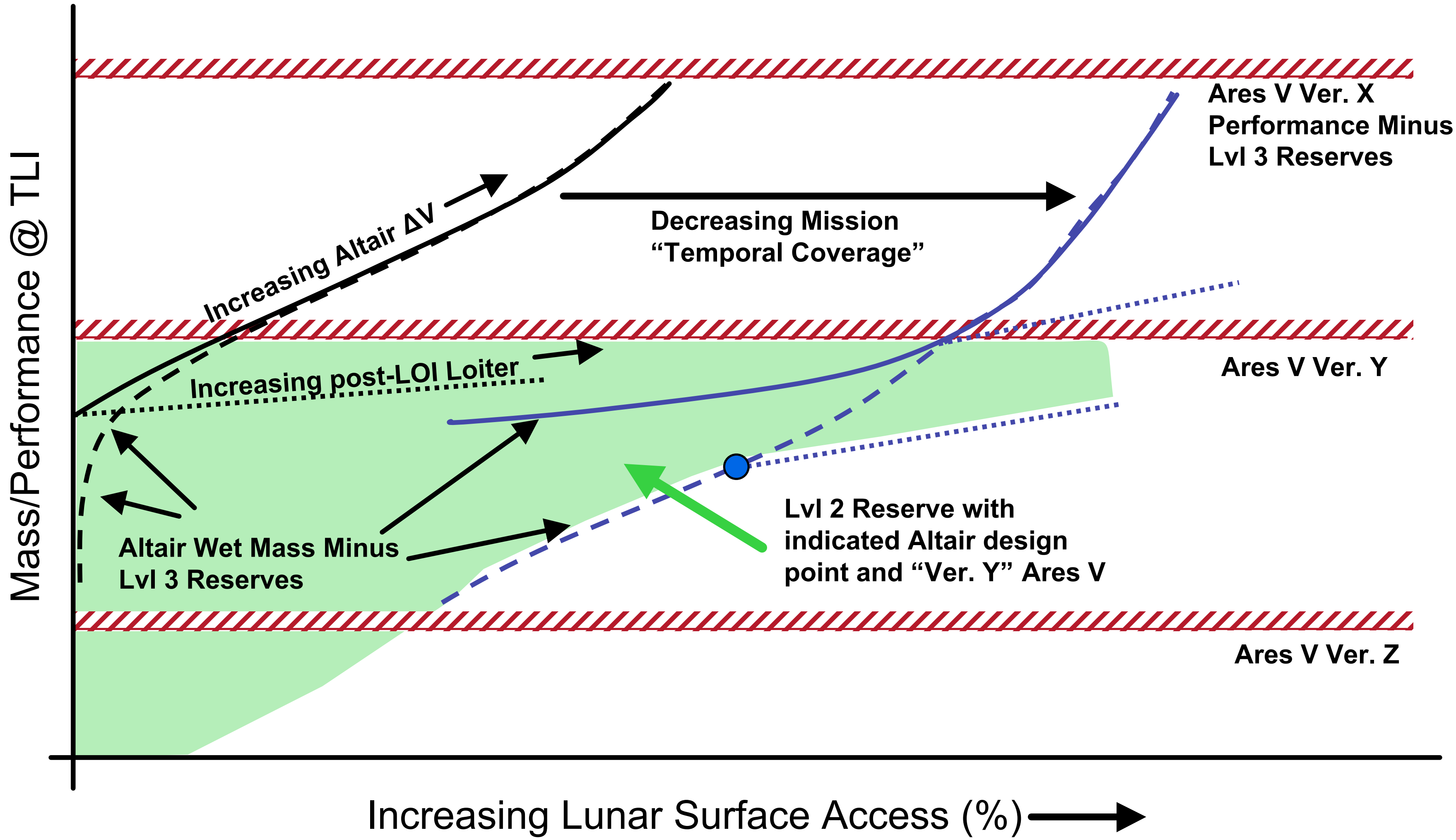
Stochastic margins assessment indicates low probability of using all Program/Project margins and reserve



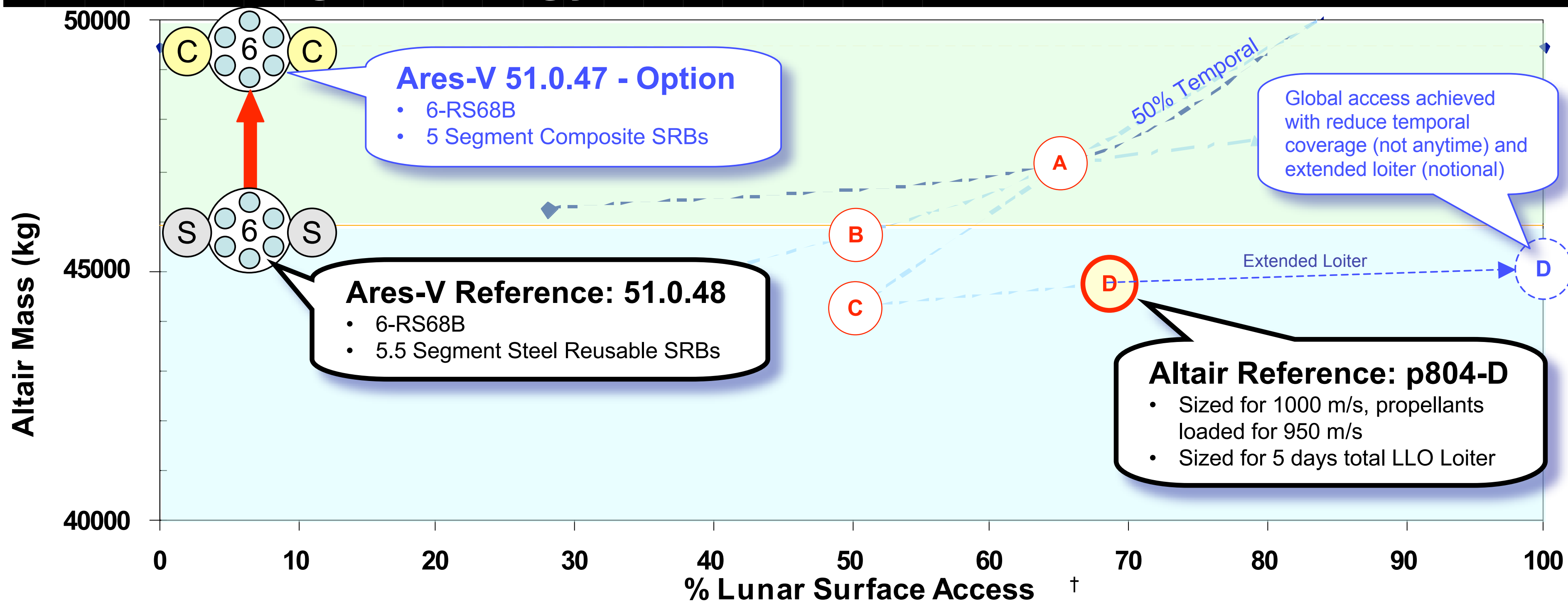




Integrated Performance



Lunar Transportation Architecture Reference / Design Strategy



	Ares-V	Ares-V Plom	Degree of Ares ISS/ Lunar Common	Altair delta-v (m/s)		Additional Transportation (Ares & G.O.) Cost (FY07 $M)*		Cargo Down in Cargo Only Mode (t)	Available Reserve @ TLI (t)				Probability of Having Adequate Total Margin	% Surface Access @ 50% Temporal
				Sized For	Load	DDT&E ($M)	Rec. ($M/yr)		Prog	Ares-V Perform	Altair			
											Reserve	Total Margin		
A	51.0.47	1/59	Medium	1000	1000	+$xxxx	+$xxx	14.6	2.3	5.0	6.5	50%	>99%	65%
B	51.0.48	1/62	High	950	950	+$xxxx	+$xx	13.8	0.1	5.0	6.3	50%	~97%	50%
C	51.0.48	1/62	High	1000	950	+$xxxx	+$xx	14.6**	1.6	5.0	4.2	40%	~97%	50%
D	**51.0.48**	**1/62**	**High**	**1000**	**950**	**+$xxxx**	**+$xx**	**14.7****	**1.2**	**5.0**	**4.3**	**40%**	**~96%**	**70%**

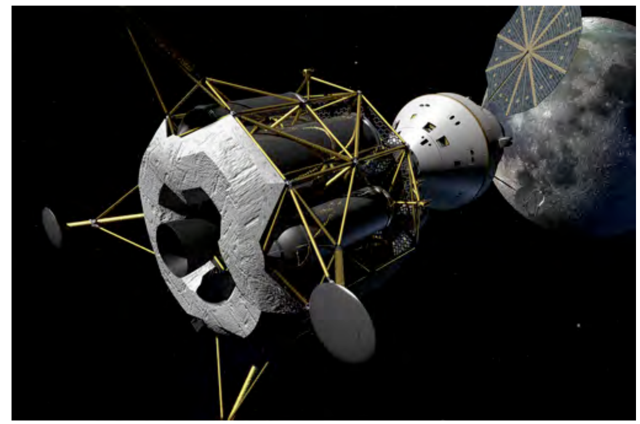
* Additional cost as compared to the 51.0.39 PPBE budget submittal
** P/L available with lander "kitted" for cargo mode and full prop loading

† Coverage based on coarse trajectory scans across the Metonic cycle. Additional surface coverage expected with further mission design refinement.

LCCR Lunar Transportation Architecture Summary

- **Ares-V**
  - Maximize commonality between Lunar and Initial Capabilities: **Ares-V 51.0.48**
    - 6 engine core, 5.5 segment PBAN steel case booster
    - Provides architecture closure with additional margin
    - High commonality with Ares I
  - Retain adequate margins:
  - Continue to study the benefits/risk of improved performance: **Ares-V 51.0.47**

- **Altair**
  - Provide a robust capability to support Lunar Outpost Missions:
    - Optimize for crew missions (**500 kg + airlock with crew**)
    - Lander cargo delivery: **~ 14,500 kg** in cargo only mode
  - Size the system for global access while allowing future mission and system flexibility
    - Size Altair tanks for **1,000 m/s LOI delta-v**
    - Size for an additional **4 days of Low-Lunar Orbit loiter** (site specific)
  - Retain adequate margins:
    - **~1,000 kg Program reserve at TLI**
    - **Minimum of 40% total Altair margin/reserve**



- **Orion**
  - Continue to mature Orion vehicle concept
  - Maintain strong emphasis on mass control
    - Continue to hold Orion control mass to **20,185 kg** at TLI
  - Maintain emphasis on evolution of Orion Block 2 to support lunar Outpost missions